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TOXICOLOGICAL AND RECALCITRANT PROPERTIES OF A PROPOSED PROPELL--ETC(U)

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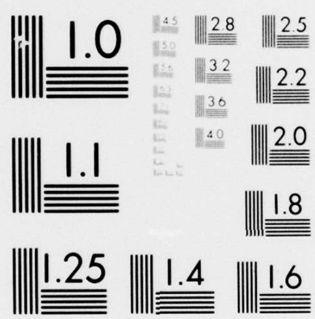

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TOXICOLOGICAL AND RECALCITRANT PROPERTIES OF A PROPOSED PROPELLANT INGREDIENT, TRIAMINOGUANIDINE NITRATE (TAGN). II. ANALYSIS OF THE DEFLAGRATION BY-PRODUCTS OF A TAGN-BASED PROPELLANT

ENVIRONICS AND HUMAN FACTORS OFFICE

DECEMBER 1976

FINAL REPORT: JUNE-NOVEMBER 1976

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AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

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This study was undertaken to examine the gaseous by-products generated from the deflagration of an experimental triaminoguanidine nitrate (TAGN)-based gun propellant and to compare these gases with those produced from standard propellants containing no TAGN. Propellants which contain TAGN are being formulated for possible future use in weapon systems employing high density, armor-piercing penetrators. The results from this study showed that TAGN-based propellants produced the same gaseous by-products as did four standard nitrocellulose (NC)-based propellants. However, quantitative variations were

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observed between the two groups. Carbon monoxide (CO) and methane (CH_4) gases were produced during the process of deflagration of both groups of propellants in quantities sufficient to require that adequate ventilation be provided when test firing within enclosed areas to insure the safety of participating personnel.

PREFACE

This technical report presents the results of research conducted by the Air Force Armament Laboratory from June 1976 to November 1976 under Air Force Exploratory Development Project 50660101.

The assistance by Mr. William Regan, Mr. Clyde Wallace, A1C Bobby Bratcher, and Mr. William Stone of the Ballistics Branch (DLDL) in the high-pressure deflagration portion of this study is acknowledged. The help provided by Mr. Bert Moy of the Ballistics Branch, Propellant Formulation Laboratory (DLDL) in several aspects of this study is also acknowledged.

The sources and manufacturers of materials and equipment used in this study are identified for reference only and do not constitute endorsement of the companies or products by the United States Air Force.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER:

Joe A. Farmer

JOE A. FARMER
Chief, Environics and Human Factors Office

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SECTION I

INTRODUCTION

The objective of this study was to examine the low-molecular-weight by-products resulting from the deflagration of the triaminoguanidine nitrate (TAGN)-based gun propellant, Rocketdyne's RGP-150. For comparative purposes, several standard propellant formulations not employing TAGN were also examined.

RGP-150 propellant is unique in that it contains TAGN as the major component. Incorporation of this compound into a nitrocellulose (NC)-cyclotetramethylenetetranitramine (HMX)-base results in reduced flame temperature and higher mass impetus (Reference 1). Propellant formulations using TAGN have recently been proposed for use in weapon systems employing high density, armor-piercing penetrators, such as the depleted uranium projectile used in the GAU-8 gun.

Recent toxicity studies have shown that several currently used propellant constituents, namely HMX and cyclotrimethylenetrinitramine (RDX), are potentially hazardous if inhaled or ingested (Reference 2). Exposure hazards are particularly evident during the manufacture and demilitarization of these substances. Presently, no information is available to adequately assess the environmental impact of TAGN. It is for this reason that TAGN and all propellants employing this substance have been under investigation by the Air Force Armament Laboratory (AFATL) and the Aerospace Medical Research Laboratory (AMRL), Wright-Patterson Air Force Base, Ohio.

In keeping with the Air Force Armament Laboratory's environmental protection policy, this study was necessary in order to:

1. Determine accurately the composition and quantity of the by-products generated from the deflagration of TAGN-based propellants.

2. Investigate the potential hazards to personnel routinely exposed to these by-products during testing and actual firing conditions.

3. Examine whether open-air burning constitutes an environmentally safe method for the disposal of obsolete munitions which contain this type of propellant.

SECTION II

MATERIALS AND METHODS

PROPELLANTS

The principal propellant under examination in this study was Rocketdyne's RGP-150. In addition, the following four NC-based propellants were studied for comparative purposes: Hercules' GAU-8 Extract, M-10, WC-870, and Triple Base. These latter four propellants are standard formulations which contain no TAGN. The composition of these propellants is presented in Table 1.

ATMOSPHERIC-PRESSURE DEFLAGRATION

Low-pressure propellant burning was accomplished in a Parr Adiabatic Calorimeter employing a No. 1104 high-pressure bomb. The propellant (approximately 0.2 - 0.5 g) was ignited under air at one atmosphere pressure by a No. 45C10 fuze wire (2.3 cal/cm).

HIGH-PRESSURE DEFLAGRATION

Propellant samples were burned in a Technoproducts Model 601 Impulse Bomb employing a 5-cubic-inch stainless steel cylinder with hostelloy head and liner (Reference 3). Ignition was accomplished with a M52-A3 electric cannon primer. Sample pressures were measured with a Kisstler 607C3 pressure transducer and were displayed on a standard cathode-ray tube for photographic duplication.

GAS ANALYSES

All gaseous samples were collected in pre-evacuated (10^{-3} Torr) stainless steel sample cylinders with an internal volume of 360 ml. Connection of cylinders to the gas chromatograph was accomplished through Nupro stainless steel 4HSW valves.

Gas analyses were carried out with a Hewlett-Packard Model 5700 Cryogenic Gas Chromatograph with thermal conductivity detector. The detector temperature and current were 250°C and 125 milliamperes, respectively. A stainless steel column, 10 feet by 1/4 inch, containing 100 - 120 mesh Porapak Q was employed. The carrier gas was ultra-pure helium, and the flow rate was 40 ml/min at 50 psi. Initial column temperature was -100°C and was maintained for 4 minutes following injection. The column was then programmed at 8°C/minute to a maximum temperature of 200°C. Final temperature was held for 8 minutes to insure complete passage of

sample through the column packing material. Peak integration was accomplished with either a Hewlett-Packard 3370 or 3380 Electronic Integrator.

TABLE 1. FORMULATIONS OF THE VARIOUS PROPELLANTS USED IN THIS STUDY

Propellant	Chemical Composition	*Percent of Total
Hercules' GAU-8 Extract	nitrocellulose (NC)	82.30
	nitroglycerine (NG)	9.37
	dibutylphthalate (DBP)	4.17
	diphenylamine (DPA)	0.54
	potassium nitrate (KNO_3)	0.56
	Hercote ($C_{5.142}H_{8.75}O_{1.838}$)	3.06
Rocketdyne's RGP-150	nitrocellulose (NC)	19.00
	triaminoguanidine nitrate (TAGN)	45.00
	cyclotetramethylenetetranitramine (HMX)	30.00
	isodecyl pelargonate (IDP)	5.00
	resorcinol	1.00
M-10	nitrocellulose (NC)	97.40
	diphenylamine (DPA)	1.00
	graphite glaze	0.10
	carbon black	0.50
	potassium sulfate (K_2SO_4)	1.00
Triple Base	nitrocellulose (NC)	28.04
	nitroglycerine (NG)	20.12
	ethylcellulose (EC)	1.00
	potassium sulfate (K_2SO_4)	0.25
	nitroguanidine (NQ)	50.59
WC-870	nitrocellulose (NC)	80.23
	nitroglycerine (NG)	9.66
	diphenylamine (DPA)	1.06
	potassium nitrate (KNO_3)	0.50
	dibutylphthalate (DBP)	7.38
	potassium sulfate (K_2SO_4)	0.38
	dinitrotoluene (DNT)	0.52
	calcium carbonate ($CaCO_3$)	0.05
	sodium sulfate (Na_2SO_4)	0.12
	graphite	0.10

*Among production batches, it is common to have minor variations in constituent percentages.

SECTION III

RESULTS AND DISCUSSION

Deflagration of propellants results in the release of numerous gaseous by-products. The types and quantities of gases produced are dependent upon (1) the ingredients comprising each propellant mixture and (2) the conditions prevailing during actual burning, such as temperature, pressure, and the availability of atmospheric oxygen.

The by-products generated from the deflagration of Rocketdyne's RGP-150 propellant are described under varying pressure conditions. A comparison of these results was made to those obtained from the burning of standard NC-based propellants containing no TAGN.

In this study each propellant was deflagrated at three different pressures. High-pressure burns (approximately 12,000 psi and 28,000 psi) were conducted in an impulse chamber which approximated conditions encountered during firing of an actual weapon. Atmospheric deflagrations (one atmosphere pressure) were performed under laboratory conditions simulating open-air burning. It was anticipated that this latter procedure would provide information concerning product formation during the burning of munitions as a means of demilitarization.

The results of this study are given in Table 2. Each value in this table is the average of duplicate sample determinations.

High-pressure deflagration of all five propellants resulted in the abundant formation (up to 61 percent) of carbon monoxide (CO). This substance is a colorless, odorless gas which is formed during the incomplete combustion of carbonaceous materials in the absence of adequate oxygen. Carbon monoxide competes with molecular oxygen for active sites on the hemoglobin molecules in the blood, and if present in significant concentrations, it can be highly toxic. Concentrations of 4,000 ppm or more for periods of less than one hour can prove lethal (Reference 4), while discomfort or severe distress can be encountered at concentrations as low as 100 ppm. Carbon monoxide should be considered significantly hazardous when concentrations of 30 ppm are attained for periods up to 8 hours or more (Reference 5).

Methane (CH_4) was also produced in appreciable amounts (up to 10 percent) during deflagration of all five propellants at high pressures. This gas, also colorless and odorless, is toxic at a threshold of approximately 10,000 ppm (Reference 6), but may be symptomatic at lower concentrations. Hazardous levels may result in respiratory failure and eventual asphyxiation if present in confined areas with inadequate ventilation.

TABLE 2. PERCENTAGES OF GASES PRODUCED WHEN SELECTED PROPELLANTS WERE BURNED UNDER HIGH AND LOW PRESSURES

Propellant	Pressure (psi)	H_2	N_2	O_2	N_2O	CO	CO_2	CH_4	C_2H_4	H_2O
RGP-150	Atm	-	84.0	8.7	-	-	5.8	-	-	1.5
RGP-150	13,000	0.2	42.2	tr	-	40.0	6.4	4.6	-	6.6
RGP-150	31,000	0.3	41.3	0.1	-	31.4	10.0	12.7	-	4.2
GAU-8 Extract	Atm	-	43.5	7.4	-	5.8	28.9	tr	-	14.4
GAU-8 Extract	11,500	0.3	15.3	0.3	-	50.9	14.8	2.3	-	16.1
GAU-8 Extract	28,000	0.3	12.7	-	-	42.0	20.8	7.1	-	17.1
M-10	Atm	-	51.0	15.7	-	1.6	22.2	-	-	9.5
M-10	13,000	0.4	16.2	-	-	57.7	20.4	1.3	-	4.0
M-10	30,000	0.2	15.6	-	-	40.9	30.2	3.2	-	9.9
WC-870	Atm	-	60.6	5.1	-	4.0	20.2	-	-	10.1
WC-870	12,000	0.3	16.2	-	-	60.6	16.3	2.4	-	4.2
WC-870	27,000	0.2	16.6	0.3	-	49.0	25.4	4.9	-	3.6
Triple Base	Atm	-	62.9	17.5	tr	5.5	4.1	-	2.6	7.4
Triple Base	13,000	tr	37.8	-	-	38.7	12.5	2.0	-	9.0
Triple Base	27,000	tr	35.9	-	-	38.9	14.2	2.1	-	8.9

In all cases, atmospheric (low-pressure) deflagration resulted in less carbon monoxide production (maximum of 5.8 percent) and only trace methane formation when compared to high-pressure burning. These reductions can be attributed to an adequate atmospheric oxygen supply, thereby facilitating more complete combustion (oxidation) of propellant ingredients.

All other gases detected during this study, with the exception of nitrous oxide (N_2O) which was present in trace amounts in one sample only, are considered relatively harmless to animal and plant life and should be of no environmental consequence.

The use of TAGN as a major constituent in a NC-HMX-based propellant had little influence on by-product formation when compared to the four standard NC-based propellants. Qualitatively, all propellants tested produced identical deflagration by-products, with the exception of Triple Base which produced additionally small amounts of ethylene (C_2H_4) and nitrous oxide (N_2O). Quantitatively, however, considerable variation of by-product formation was apparent. As an example, the levels of both methane (CH_4) and nitrogen gas (N_2) were generally elevated in the RGP-150 samples, while carbon dioxide (CO_2) and carbon monoxide (CO) production were somewhat lowered. This increase in nitrogen gas (N_2) formation can readily be explained as a consequence of the higher nitrogen content of RGP-150 due to the presence of TAGN. In a similar manner, the elevated methane (CH_4) levels and respective decreases in carbon dioxide (CO_2) and carbon monoxide (CO) formation can be attributed to a lower net oxygen content. As a general rule, therefore, increased nitrogen content of the propellant promotes nitrogen gas (N_2) formation, while limited oxygen availability results in production of greater quantities of reduced carbon compounds such as methane (CH_4) and proportionately less amounts of the oxidized forms, viz., carbon dioxide (CO_2) and carbon monoxide (CO).

SECTION IV

CONCLUSIONS

This report provides a detailed analysis of the deflagration products of four currently used and one proposed Air Force propellant. Two potentially hazardous gases--carbon monoxide (CO) and methane (CH_4)--have been identified under conditions resembling those encountered during normal test and evaluation procedures. Both gases should be considered hazardous (1) in confined areas lacking adequate ventilation such that dissipation to permissible levels is not achieved, or (2) wherever relatively chronic levels are attained for prolonged periods, thus maximizing the dangers associated with long-term intolerance to these substances.

Upon burning, Rocketdyne's RGP-150 propellant produced the same gaseous by-products, although quantitatively different, as did the four NC-based propellants tested. The use of TAGN in this proposed propellant did not significantly alter typical by-product formation nor did it appreciably increase the potential hazards associated with the use of propellants.

Open-air burning in restricted areas should be considered an environmentally safe means for the disposal of the propellants studied for this report as long as adequate measures are taken to insure the safety of personnel in the immediate area.

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